~~Universal Soil Loss~~ Equation

Erosion

JVB

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PROCEDURE FOR

COMPUTING SHEET AND RILL EROSION (IV)

ON PROJECT AREAS

PROCEDURE FOR COMPUTING SHEET AND RILL EROSION ON PROJECT AREAS

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This technical release is based on data developed by Walter H. Wischmeier and his associates in ARS. The procedure was prepared by many SCS specialists, principally, John Holeman, Geologist (Sedimentation); Joseph W. Turelle, Agronomist; and R. C. Barnes, Agricultural Engineer, all of Washington, D. C. The example was prepared by Graham W. Renfro, Geologist, STSC, Fort Worth, Texas.

PROCEDURE FOR
COMPUTING SHEET AND RILL EROSION ON
PROJECT AREAS

INTRODUCTION

Since the late 1940's, SCS geologists, who are responsible for estimating sediment yields, have been using the Musgrave Equation (1) to compute the amount of sheet and rill erosion occurring in a watershed. The Musgrave Equation has been a part of one of several procedures used to estimate sediment yields. Additional research on erosion has resulted in the development of the Universal Soil-Loss Equation (USLE) by the Agricultural Research Service (ARS) in cooperation with the SCS and certain state experiment stations (2). The USLE has been used only on cropland, hayland, and pastures in rotation. Erosion factors reflecting the effect of cover on uncultivated land areas have been lacking. Since the USLE has been used throughout much of the country as a tool in planning land treatment on individual operating units, it was recommended that the use of this equation with its refined data be extended to watersheds and other project areas in which the SCS has responsibilities. In order to do this, additional plant cover factors (C) were needed for permanent pastureland, rangeland, woodland, and idle land to estimate the effect of these types of cover on soil losses.

During a conference of SCS and ARS personnel in November of 1971, needed factors for types of cover on uncultivated lands were discussed and tentatively agreed upon. Subsequent analyses by the ARS provided values for these factors as presented in Tables 2 and 3. These factors are for use in the USLE to estimate sheet and rill erosion for SCS project work such as watersheds, river basin studies, and resource conservation and development (RC&D) projects.

The determination of the values of the factors to be used in the USLE for project work will be a team effort. The state resource conservationist, agronomist, and/or district conservationist provide the geologist with C values. Information is needed not only for rotations to be used on cropland, and management practices on pastureland, rangeland, and woodland, but also the amount or percent of land treatment which will be applied during the project installation period. The complete USLE is A = RKLSCP

where A is the computed soil loss (sheet and rill erosion) in tons per acre per year. A is not the sediment yield;
R, the rainfall factor, is the number of erosion-index units in a normal year's rain;
K, the soil-erodibility factor, is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow, on a 9-percent slope 72.6 feet long;
L, the slope-length factor, is the ratio of the soil loss from the field slope length to that from a 72.6 ft. length on the same soil type and gradient;
S, the slope-gradient factor, is the ratio of soil loss from the field gradient to that from a 9-percent slope;

C, the cropping management factor, is the ratio of soil loss from a field with specified cropping and management to that from the fallow condition on which the factor K is evaluated;

P, the erosion-control practice factor, is the ratio of soil loss with contouring, stripcropping, or contour irrigated furrows to that with straight-row farming, up-and-down slope.

RAINFALL FACTOR (R)

The energy of moving water detaches and transports soil materials. The energy-intensity (EI) parameter measures total raindrop energy of a storm and its relation to the maximum 30-minute intensity. Soil losses are linearly proportional to the number of EI units. The EI values are summed to obtain an annual rainfall-erosivity index for a given location. This annual index serves as the R factor and has been computed for the area east of the Rocky Mountains and can be obtained from figure 1. This figure differs from figure 1, Agricultural Handbook No. 282 (4) in that average annual values of the rainfall factor R do not exceed 350. The Agricultural Research Service (ARS) has determined that the higher values shown in Agricultural Handbook No. 282 were unrealistically high. They recommended that 350 be the maximum R value used in the USLE in the continental United States east of the Rocky Mountains.

EI factors have not been evaluated from actual rainfall data west of the Rocky Mountains. (see Fig. 1) An interim procedure for determining R values for that area is covered in a West TSC Technical Note (3). Hawaii has also issued a Technical Note which gives information on R values for that state (2). Individuals interested in those areas should consult the appropriate Technical Note.

SOIL-ERODIBILITY FACTOR (K)

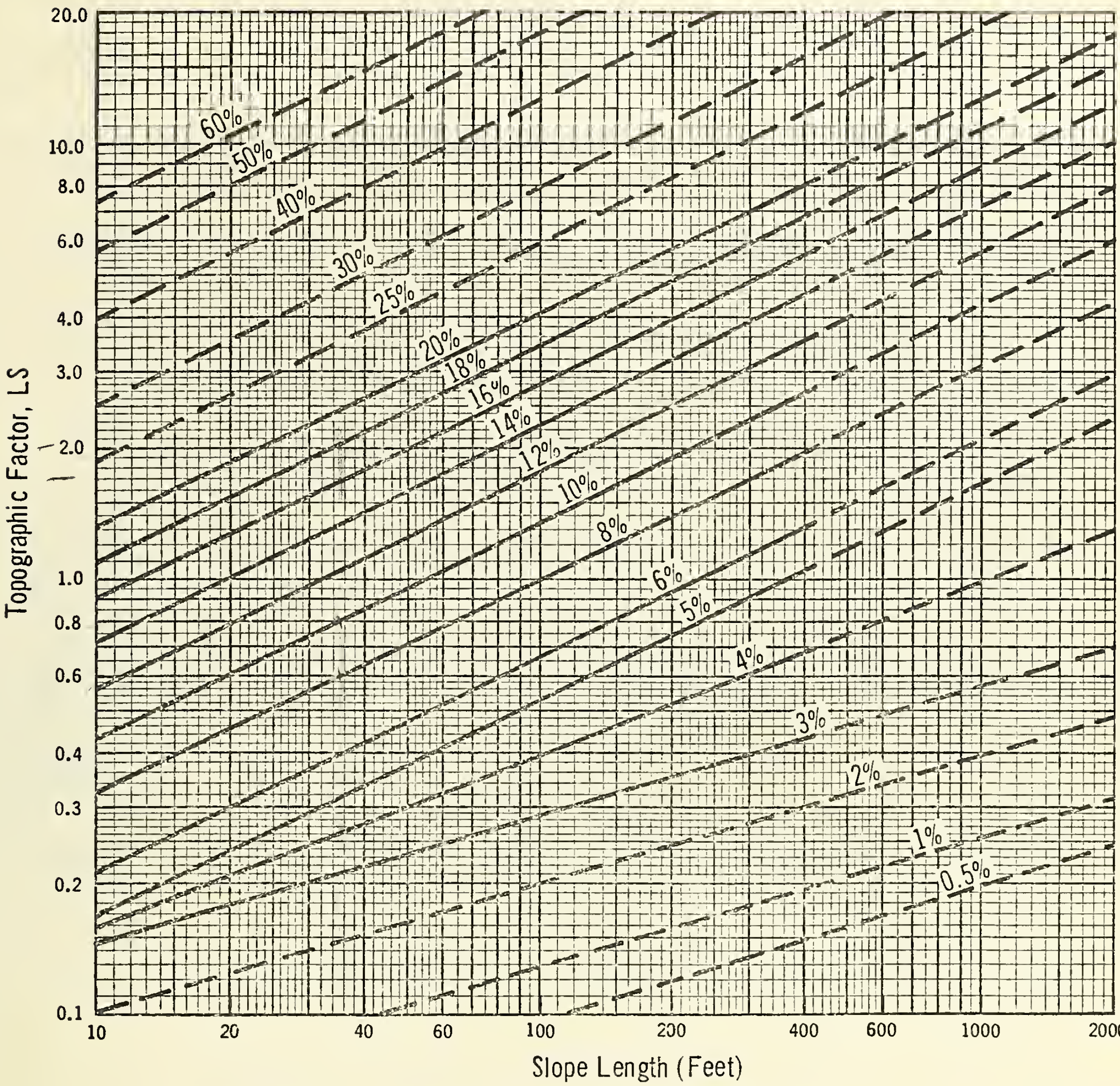
The capability of a soil surface to resist erosion is a function of the soil's physical and chemical properties. The most significant soil characteristics affecting soil erodibility are texture, organic matter content, soil structure and permeability. The K values are assigned to named kinds of soil and may be obtained from the soil scientist, the technical guides, or published lists.

SLOPE LENGTH (L) AND SLOPE GRADIENT (S)

Soil loss is affected by both length and degree of slope. For convenience in the field application of these factors they are combined into a single topographic factor, LS.

The LS factor for gradients up to 60% and slope lengths to 2000 feet is obtained from the Slope-Effect Chart, figure 2. Similar data in tabular form is shown in Table 1. Values shown on the chart and table for slopes of less than 3%, greater than 20%, or longer than 400 feet, represent extrapolations of the formula beyond the range of research data. Computed soil loss obtained using such LS values may require adjustment based on experience and judgment.

Figure 2 SLOPE-EFFECT CHART (Topographic Factor, LS)*



*The dashed lines represent estimates for slope dimensions beyond the range of lengths and steepnesses for which data are available. The curves were derived by the formula:

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{430x^2 + 30x + 0.43}{6.57415}\right)$$

where λ = field slope length in feet and $m = 0.5$ if $s = 5\%$ or greater, 0.4 if $s = 4\%$, and 0.3 if $s = 3\%$ or less; and $x = \sin\theta$. θ is the angle of slope in degrees.

Table 1 Slope-Effect Table (Topographic Factor, LS)

Percent	Slope Length in Feet													
Slope	10	20	40	60	80	100	110	120	130	140	150	160	180	200
0.2	0.04	0.05	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10
0.3	0.04	0.05	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11
0.4	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11
0.5	0.05	0.06	0.08	0.08	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12
1.0	0.06	0.08	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.16
2.0	0.10	0.12	0.15	0.17	0.19	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.25
3.0	0.14	0.18	0.22	0.25	0.27	0.29	0.30	0.30	0.31	0.32	0.32	0.33	0.34	0.35
4.0	0.16	0.21	0.28	0.33	0.37	0.40	0.42	0.43	0.44	0.46	0.47	0.48	0.51	0.53
5.0	0.17	0.24	0.34	0.41	0.48	0.54	0.56	0.59	0.61	0.63	0.66	0.68	0.72	0.76
6.0	0.21	0.30	0.43	0.52	0.60	0.67	0.71	0.74	0.77	0.80	0.82	0.85	0.90	0.95
8.0	0.31	0.44	0.63	0.77	0.89	0.99	1.04	1.09	1.13	1.17	1.21	1.25	1.33	1.40
10.0	0.43	0.61	0.87	1.06	1.23	1.37	1.44	1.50	1.56	1.62	1.68	1.73	1.84	1.94
12.0	0.57	0.81	1.14	1.40	1.61	1.80	1.89	1.98	2.06	2.14	2.21	2.28	2.42	2.55
14.0	0.73	1.03	1.45	1.78	2.05	2.29	2.41	2.51	2.62	2.72	2.81	2.90	3.08	3.25
16.0	0.90	1.27	1.80	2.20	2.54	2.84	2.98	3.11	3.24	3.36	3.48	3.59	3.81	4.01
18.0	1.09	1.54	2.17	2.66	3.07	3.43	3.60	3.76	3.92	4.06	4.21	4.34	4.61	4.86
20.0	1.29	1.82	2.58	3.16	3.65	4.08	4.28	4.47	4.65	4.83	5.00	5.16	5.47	5.77
25.0	1.86	2.63	3.73	4.56	5.27	5.89	6.18	6.45	6.72	6.97	7.22	7.45	7.90	8.33
30.0	2.52	3.56	5.03	6.16	7.11	7.95	8.34	8.71	9.07	9.41	9.74	10.06	10.67	11.25
40.0	4.00	5.66	8.00	9.80	11.32	12.65	13.27	13.86	14.43	14.97	15.50	16.01	16.98	17.90
50.0	5.64	7.97	11.27	13.81	15.94	17.82	18.69	19.53	20.32	21.09	21.83	22.55	23.91	25.21
60.0	7.32	10.35	14.64	17.93	20.71	23.15	24.28	25.36	26.40	27.39	28.36	29.29	31.06	32.74

Table 1 Continued

Percent Slope	Slope Length in Feet													
	300	400	500	600	700	800	900	1000	1100	1200	1300	1500	1700	2000
0.2	0.11	0.12	0.13	0.14	0.15	0.15	0.16	0.16	0.17	0.17	0.18	0.19	0.19	0.20
0.3	0.12	0.13	0.14	0.15	0.16	0.16	0.17	0.18	0.18	0.18	0.19	0.20	0.21	0.22
0.4	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.19	0.20	0.20	0.21	0.22	0.23
0.5	0.14	0.15	0.16	0.17	0.18	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.24
1.0	0.18	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.27	0.28	0.29	0.30	0.32
2.0	0.28	0.31	0.33	0.34	0.36	0.38	0.39	0.40	0.41	0.42	0.43	0.45	0.47	0.49
3.0	0.40	0.44	0.47	0.49	0.52	0.54	0.56	0.57	0.59	0.61	0.62	0.65	0.67	0.71
4.0	0.62	0.70	0.76	0.82	0.87	0.92	0.96	1.01	1.04	1.08	1.12	1.18	1.24	1.33
5.0	0.93	1.07	1.20	1.31	1.42	1.52	1.61	1.69	1.78	1.86	1.93	2.07	2.21	2.40
6.0	1.17	1.35	1.50	1.65	1.78	1.90	2.02	2.13	2.23	2.33	2.43	2.61	2.77	3.01
8.0	1.72	1.98	2.22	2.43	2.62	2.81	2.98	3.14	3.29	3.44	3.58	3.84	4.09	4.44
10.0	2.37	2.74	3.06	3.36	3.62	3.87	4.11	4.33	4.54	4.74	4.94	5.30	5.65	6.13
12.0	3.13	3.61	4.04	4.42	4.77	5.10	5.41	5.71	5.99	6.25	6.51	6.99	7.44	8.07
14.0	3.98	4.59	5.13	5.62	6.07	6.49	6.88	7.26	7.61	7.95	8.27	8.89	9.46	10.26
16.0	4.92	5.68	6.35	6.95	7.51	8.03	8.52	8.98	9.42	9.83	10.24	11.00	11.71	12.70
18.0	5.95	6.87	7.68	8.41	9.09	9.71	10.30	10.86	11.39	11.90	12.38	13.30	14.16	15.36
20.0	7.07	8.16	9.12	9.99	10.79	11.54	12.24	12.90	13.53	14.13	14.71	15.80	16.82	18.24
25.0	10.20	11.78	13.17	14.43	15.59	16.66	17.67	18.63	19.54	20.41	21.24	22.82	24.29	26.35
30.0	13.78	15.91	17.79	19.48	21.04	22.50	23.86	25.15	26.38	27.55	28.68	30.81	32.80	35.57

PLANT COVER OR CROPPING MANAGEMENT FACTOR (C)

The C factor values relate to the effect of cover. These average values may be for a period as long as 100 years, if that is the evaluation period of a project area.

The erosion equation, as used on cropland and hayland, employs established factor relationships to estimate a basic soil-loss that is determined by the soil properties, topographic features, certain conservation practices, and expected rainfall patterns for a specific field. The basic soil loss is the rate at which the field would erode if it were continuously in tilled fallow. The equation's factor C indicates the percentage of this potential soil loss that would occur if the surface were partially protected by some particular combination of cover and management. The Musgrave cover factors cannot be directly substituted for the C factor in the USLE because the base conditions from which the cover factors were developed are different, (continually tilled fallow for USLE as opposed to up-and-down hill row crops for Musgrave).

Extension of the factor C to completely different situations is based upon three separate and distinct but interrelated zones of influence: (a) the vegetative cover in direct contact with the soil surface; (b) canopy cover; and (c) effects at and beneath the surface (5).

Factor (C) for Pasture, Range and Idle Land

The effects of the three zones of influence were used in the estimation of factor C for pastureland, rangeland and idle land as shown in Table 2.

Factor (C) for Woodland

Permanent woodland differs in several respects from the situations covered by Table 3. A layer of compacted decaying duff or litter several inches thick is extremely effective against water erosion. Existing research data, though limited, supports a C value as low as .001 for woodland with a 100% cover of such duff. Computed values of the erosion equation's factor C for some woodland situations are presented in Table 3.

Factor (C) for Cropland and Hayland

This factor is a measure of the effects of cropping sequences, cover and management on soil losses from cropland and hayland. Factors have been computed, on a local basis, for conventional and conservation (minimum) tillage systems of farming.

Table 2. "C" Values for Permanent Pasture, Rangeland, and Idle Land[1/]

Vegetal Canopy		Cover That Contacts the Surface						
Type and Height of Raised Canopy[2/]	Canopy Cover[3/] %	Type[4/]	Percent Ground Cover 0	20	40	60	80	95-100
Column No.:	2	3	4	5	6	7	8	9
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds	25	G	.36	.17	.09	.038	.012	.003
or short brush		W	.36	.20	.13	.082	.041	.011
(0.5 m fall ht.)	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
Appreciable brush	25	G	.40	.18	.09	.040	.013	.003
or brushes		W	.40	.22	.14	.085	.042	.011
(2 m fall ht.)	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
(4 m fall ht.)	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

1/ All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years.

2/ Average fall height of waterdrops from canopy to soil surface: m = meters.

3/ Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

4/ G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface, and/or undecayed residue.

Table 3. "C" Factors for Woodland

Tree Canopy % of Area [1/]	Forest Litter % of Area [2/]	Undergrowth [3/]	"C" Factor
100-75	100-90	Managed[4/]	.001
		Unmanaged[4/]	.003-.011
70-40	85-75	Managed	.002-.004
		Unmanaged	.01-.04
35-20	70-40	Managed	.003-.009
		Unmanaged	.02- .09[5/]

[1/] When tree canopy is less than 20%, the area will be considered as grassland, or cropland for estimating soil loss. See Table 1.

[2/] Forest litter is assumed to be at least two inches deep over the percent ground surface area covered.

[3/] Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

[4/] Managed - grazing and fires are controlled.
Unmanaged - stands that are overgrazed or subjected to repeated burning.

[5/] For unmanaged woodland with litter cover of less than 75%, C values should be derived by taking 0.7 of the appropriate values in Table 1. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

EROSION-CONTROL PRACTICE FACTOR (P)

This factor accounts for control practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff concentration, and runoff velocity. Practices for which P factors have been established are contouring, contour stripcropping, and contour irrigated furrows. Terraces and diversions, where used, reduce the length of slope only.

The practice values for contouring, contour stripcropping (strips of sod or meadow alternated with strips of row crop or small grain), and contour irrigated furrows are:

Land Slope %	P Values			
	Contouring	Contour Stripcropping	Contour Irrigated Furrows	Terracing[1/]
2.0 to 7	0.50	0.25	0.25	0.10
8.0 - 12	0.60	0.30	0.30	0.12
13.0 - 18	0.80	0.40	0.40	0.16
19.0 - 24	0.90	0.45	0.45	0.18

[1/] For prediction of contribution to off-field sediment load.

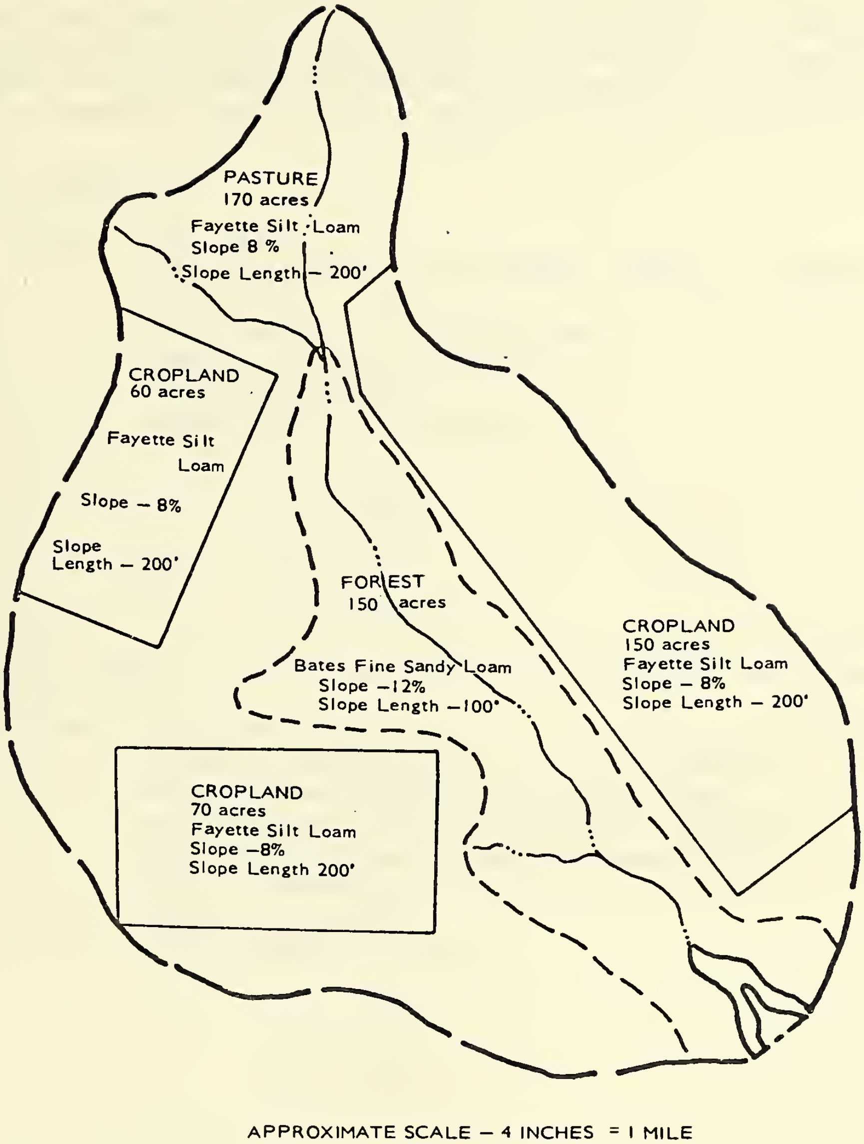


Figure 3. – A Hypothetical 600 – Acre Watershed for Use in Example.

EXAMPLE OF USE OF UNIVERSAL SOIL LOSS EQUATION IN WATERSHED PLANNING

Assume a watershed area of 600 acres above a proposed floodwater retarding structure in Fountain County, Indiana. Compute the average annual soil loss from sheet erosion for present conditions and for future conditions after recommended land treatment is applied on all land in the watershed.

Present Conditions

Cropland - 280 acres
Continuous corn with residue removed - average yield - 70 bu./ac.
Cultivated up and down slope
Soil - Fayette silt loam
Slope - 8 percent
Slope length - 200 feet

R = 185
K = .37
LS = 1.4
C = .43
P = 1.00

A = 185 X .37 X 1.4 X .43 X 1.0 = 41.2 Tons/Acre/Year Soil Loss

Pasture - 170 acres
Canopy of short brush - 0.5 m fall height
Percent cover provided by canopy - 50%
Surface cover - grass and grasslike plants
Percent of surface or ground cover - 80%
Soil - Fayette silt loam
Slope - 8 percent
Slope length - 200 feet

R = 185
K = .37
LS = 1.4
C = 0.012

A = 185 X .37 X 1.4 X .012 = 1.15 Tons/Acre/Year

Forest - 150 acres

Percent of area covered by tree canopy - 30%
Percent of area covered by litter - 50%
Undergrowth - unmanaged
Soil - Bates silt loam
Slope - 12 percent
Slope length - 100 feet

R = 185
K = .32
LS = 1.8
C = 0.5

A = 185 X .32 X 1.8 X .05 = 5.3 Tons/Acre/Year

Future Conditions

Cropland - 280 acres

Rotation of wheat, meadow, corn, corn with residue left
Contour stripcropped
Soil - Fayette silt loam
Slope - 8 percent
Slope length - 200 feet

R = 185
K = .37
LS = 1.4
C = .119
P = .3

A = 185 X .37 X 1.4 X .119 X .3 = 3.4 Tons/Acre/Year

Pasture - 170 acres

With improved management:

Canopy cover decreased to 25 percent with 4 m fall height
Ground cover increased to 95 percent (for area not protected by canopy)
Soil - Fayette silt loam
Slope - 8 percent
Slope length - 200 feet

R = 185
K = .37
LS = 1.4
C = .003

A = 185 X .37 X 1.4 X .003 = 0.29 Tons/Acre/Year

Forest - 150 acres

With improved management:

Canopy cover increased to 60 percent
Litter cover increased to 80 percent
Undergrowth - managed
Soil - Bates silt loam
Slope - 12 percent
Slope length - 100 feet

R = 185
K = .32
LS = 1.8
C = .003

A = 185 X .32 X 1.8 X .003 = 0.32 Tons/Acre/Year

Summary of Average Annual Soil Losses

Present Conditions

Cropland - 280 acres X 41.2 tons/ac.	=	11,536 tons/year
Pasture - 170 acres X 1.15 tons/ac.	=	196 tons/year
Forest - 150 acres X 5.3 tons/ac.	=	795 tons/year

Future Conditions

Cropland - 280 acres X 3.4 tons/ac.	=	952 tons/year
Pasture - 170 acres X .29 tons/ac.	=	49 tons/year
Forest - 150 acres X .32 tons/ac.	=	48 tons/year

These values are entered on form SCS-ENG-309 (Rev. 1974) and the procedure set forth in Technical Release No. 12 (Rev.), "Procedure -Sediment Storage Requirements for Reservoirs," is followed to obtain the sediment yield at the proposed floodwater retarding structure.

References

(1) Musgrave, G. W., 1947, The Quantative Evaluation of Factors in Water Erosion, A First Approximation. Jour. Soil and Water Conservation. 2: 133-138.

(2) Soil Conservation Service, 1974, Guidelines for Use of the Universal Soil Loss Equation in Hawaii, Technical Notes, Hawaii, No. 3, in press.

(3) Soil Conservation Service, 1974, Universal Soil Loss Equation, Technical Notes, Conservation Agronomy No. 32, West Technical Service Center-Portland, Oregon

(4) Wischmeier, Walter H. and Smith, D. D., 1965, Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains. USDA ARS. Agricultural Handbook No. 282.

(5) Wischmeier, Walter H., 1971, Approximating the Erosion Equation's Factor C for Uncultivated Land Areas. From Unpublished Report of ARS-SCS Technical Conference, Des Plaines, Illinois, November 22-24.